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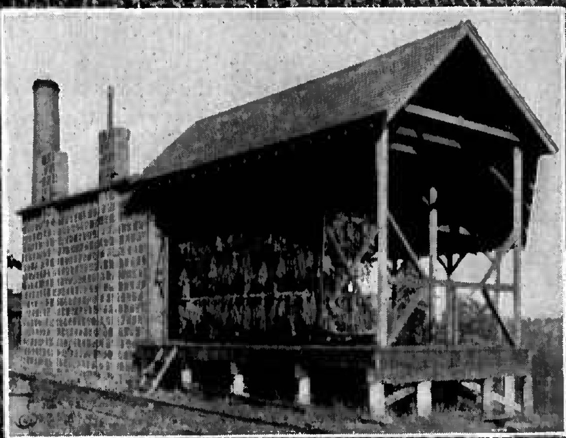
UNITED STATES DEPARTMENT OF AGRICULTURE

DRYING CRUDE DRUGS



THE application of a few fundamental principles of drying would result in making more marketable a considerable portion of the crude-drug materials that are gathered.

Success in drying depends chiefly upon the careful control of temperature and the flow of air.

In this bulletin two driers are described and the method of construction presented in detail. Either may be constructed by anyone familiar with the use of carpenter's tools from material which is everywhere available. The manner of drying is described and also the subsequent storage of the dried material.

Contribution from the Bureau of Plant Industry
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DRYING CRUDE DRUGS.

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DRYING IS AN IMPORTANT PROCESS in the production of crude vegetable drugs for the market, and material that has been carefully gathered and harvested can be made unmarketable by improper methods of drying or curing. After the material is gathered, even a little care in drying will more than repay the collector for the work and expense involved. It must be understood, however, that poor material already in a moldy, partly decayed, or otherwise unsatisfactory condition can not be made into a good product by any amount of care in drying.

The appearance of crude drugs is often a criterion of their market value; therefore the careful producer will so control the drying operations as to produce the best-appearing drug at the minimum expense.

PRINCIPLES OF DRYING.

The object of drying is to remove sufficient moisture from the product to insure good keeping qualities. The removal of moisture from green drug plants prevents molding, the action of enzyms, and chemical or other changes which are brought about by the presence of excess moisture. To obtain satisfactory results in drying such plants, provision must be made (1) for the continuous flow of air at a suitable rate through the drying material and (2) for the control of temperature.

AIR FLOW.

Moisture to be removed from the plant tissues of green drug material must be converted into water vapor, which in turn must be taken up by the air. When in free circulation the air rarely ever becomes entirely saturated with water vapor and is practically always capable of absorbing more. If, however, the air is not in free

circulation for any reason, it eventually becomes saturated with moisture and will not take up any more. To obtain proper drying, therefore, it is necessary to keep the air in motion, constantly bringing fresh volumes of air into contact with the material being dried. If, however, the air is kept in motion, fresh volumes are constantly brought into contact with the drying material, and evaporation from the material is not retarded but hastened.

During the drying process the material may become infected with molds, may change color, and may otherwise deteriorate, but it will eventually become thoroughly dry; that is, it will reach a condition in which moisture in the tissues is no longer converted into water vapor and taken up by the air.

Careful attention to the rate of air flow is important, particularly at the beginning of the drying operation. The moisture contained in the interior tissues of the drug reaches the surface relatively slowly. Therefore, if the surface moisture is removed more rapidly than it can be replaced by interior moisture the outer layers of cells will tend to dry out and become hard while the interior is still moist. This condition is likely to occur when large volumes of air are circulated, and especially if the air is circulated while warm. The hardening of the outer portion of the drug is undesirable, especially with root drugs, since deterioration is likely to take place soon after the material is removed from the drier, because of the interior moisture.

TEMPERATURE.

At any specified temperature a given volume of air can hold only a definite quantity of water vapor. The raising or lowering of the temperature increases or decreases the amount of moisture that this volume of air can hold. In the drier illustrated in figure 6 each compartment contains approximately 200 cubic feet of air. Under ordinary atmospheric pressure the air in a single compartment at 32° F. can hold slightly less than 1 ounce of water vapor; at 70°, 3.54 ounces; at 100°, 8.9 ounces; at 150°, slightly over 2 pounds; at 200°, almost 6 pounds; and at 212°, 7½ pounds.

Since the air always contains some moisture, it must not be inferred that 200 cubic feet of air will at any given temperature absorb the maximum quantity of water vapor which it can contain at this temperature. For example, 200 cubic feet of air at 100° F. may already contain 2.5 ounces of water vapor, and since this volume of air can only hold 8.9 ounces when entirely saturated the difference between 8.9 ounces and 2.5 ounces, or 6.4 ounces, is the quantity of additional water vapor which 200 cubic feet can absorb. Furthermore, the air passed through a drier is never allowed to become saturated, even as it approaches the outlet, for if it does become

saturated with water vapor it deposits some of its moisture on reaching a lower temperature than the one at which it became saturated. In that case the contents of the upper trays in the drier would become wet with external moisture and would not dry out satisfactorily until the lower trays had become dry.

After absorbing the first 60 per cent of its moisture-holding capacity the air takes up moisture very slowly to the point of saturation. It is advisable to provide such a flow of air through the drier as will contain approximately 60 per cent of its moisture-carrying capacity as it leaves the outlet. Later on, as the drug becomes more and more dry, the air will absorb less and less additional water vapor, and at the end of the drying operation will contain no moisture evaporated from the drug. The material is then dry.

For the proper drying of crude drugs the upper range of temperature varies with the product to be dried, but it should never exceed 170° F., the temperature at which 200 cubic feet of air can hold 3.22 pounds of water vapor. This temperature should not be reached, however, until the drug is nearly dry; in fact, better results are usually obtained by maintaining a temperature not over 120° F., which should be reached only after the drug has dried for some time. Too high a temperature at the beginning brings about the same condition as the circulation of too great a volume of air, namely, the hardening of the surface tissues, with a retarding and ultimate stopping of evaporation of the interior moisture.

Control of the temperature and regulation of the air flow are the two main principles of drying. The most efficient method is to combine the two and force heated air over the material at such a rate that it will remove the moisture from the surface just as rapidly as it comes from the interior of the material being dried. To determine this point is a matter largely of experience and practice. To pass beyond it causes the moisture to be rapidly extracted from the outside tissues of the drug, so that they become hard and thus retard or often completely stop the evaporation of the interior moisture. In addition, the heat which should be used to assist in vaporizing the moisture is lost, with a consequent increase in the cost of drying.

Fresh crude drugs should be dried only at such a rate that the loss of moisture is constant and relatively slow. It is better to dry them over a long period of time at a slow rate of evaporation of the interior moisture than to dry them over a short period with a resulting product which is easily subject to deterioration or which is "off" in color. The increased price for the article of higher quality will more than compensate for the additional expense involved in the slower drying.

Control of the drying operation is determined only by the nature of the material to be dried and the desired appearance of the finished

product. It may be generally stated, however, that leaf and herb drugs should be dried at moderate temperatures and root drugs at somewhat higher temperatures, the degree of heat to be used depending upon the condition of the green material. Flowers require low temperatures, whereas barks can often be dried at relatively high temperatures. Drugs in which the value depends on aromatic principles that are easily volatilized must be dried at a low temperature, in order that the volatile principle may not be lost through evaporation.

FIG. 1.—Burdock roots being dried in the sun.

METHODS OF DRYING.

Crude drugs can be dried either in the air or by means of artificial heat. When dried in the air, either sun-drying or shade-drying is employed, depending upon the type of material and the appearance desired for the finished product. The term "sun-drying" is self-explanatory. This method can be employed only with drugs in which the quality or appearance is not unfavorably affected by the action of direct sunlight. It is the least expensive, of course, of any method. Figure 1 shows a quantity of burdock roots being dried in the sun. The roots are split and then spread on trays to facilitate handling night and morning or on rainy days. Dried in this manner burdock root is in first-class marketable condition. The period of drying of the burdock shown in the illustration extended over several days, and as no rains occurred during that time the trays were left in the sun continuously from early morning until just before sundown, being moved about as required to face the sun.

In shade-drying the direct effect of the sun's rays is eliminated. Shade is used to protect the material from the action of direct sun-

light, which destroys the natural color of the drug. Certain aromatic drugs, such as sage, peppermint, and wormwood, are perhaps better in quality and appearance if dried in the shade without the use of artificial heat, unless the heat is carefully controlled and kept relatively low. Figure 2 shows a quantity of wormwood herb being dried in the shade. The fresh herb was spread in thin layers on wires strung across the driveway of a double corncrib. The sun's rays were shut off by the roof of the corncrib and the slat construction allowed a free circulation of air. After several days the herb was completely dry and had a pleasing silver-green natural color. The expense of drying was very slight.

FIG. 2.—Wormwood herb being dried in the shade.

All things considered, drying by means of artificial heat is probably the most satisfactory method, and some of the most practical ways of doing it are described in this bulletin. A careful workman can safely use artificial heat to dry even the most delicate aromatic drugs. Where large quantities are to be dried in a relatively short period of time artificial heat becomes a necessity. If, however, only small quantities are to be dried air-drying is the cheapest and perhaps the most practicable method, but some arrangement should be provided whereby artificial heat may be employed during long rainy periods or when other conditions are not favorable for air-drying.

DRYING EQUIPMENT.

The equipment necessary for the proper and successful drying of crude drugs depends upon the nature of the drug to be dried, the weather conditions during the period of drying, and the quantity of material to be handled.

Crude drugs fall naturally into one of the following classes: Leaves, herbs, roots, rhizomes, barks, fruits, and flowers. Leaf drugs consist either of the whole leaf or the leaf and a small portion of the upper end of the stalk. Herbs consist of the portion of the plant above ground and may contain flowers or fruits. Root drugs consist of the root of the plant, either whole or with the bark removed. Rhizomes are the underground stems, which are sometimes improperly called roots. Barks consist of the bark either of the aerial part of the plant or of the root. The latter are designated as root barks to differentiate them from other barks. Fruit drugs consist of the whole fruits, whereas seed drugs are only the seed of the fruit. Flower drugs consist either of the whole flower or of certain portions of the flower.

The producer of crude drugs, whether he is a collector or grower, must take into account all these classes of drugs, since in all probability he will dry some of each class. Because of this range of materials and the variation in weather conditions over the long period of time in which these various drugs mature, it is best to provide a drying apparatus in which artificial heat can be employed when necessary.

It is assumed that the material to be dried comes to the drying house in proper condition; that is, free from foreign matter, such as dirt, stones, and sticks, and that after drying it can be put into shape for shipment with very little extra work, such as cleaning or sorting. Some drugs must be sorted or graded, and this can be done either before or after drying, depending upon the choice of the producer.

Material to be air-dried in the sun, can be spread on trays, boards, sheets of burlap, papers, or any other suitable and convenient material. If the lots to be dried are not large, they can be spread on the southern roof of a low building, from which they can easily be removed at night or in the event of rain.

For air-drying in the shade, some arrangement should be provided whereby the material can be left until dry. This can be effected in two ways: The material can be spread out on some sort of convenient tray or it can be hung on wires or strings, the method depending upon the nature of the products to be dried. When the whole herb is to be dried it has been found very convenient to hang it on wires stretched in an attic or in a building where there is a good circulation of air. In the case of belladonna, which was dried in the experiments of the writer before the leaves were removed, the herb was hung by catching the wire at the union of the lowest leaf and the stalk. It was found that each linear foot of wire accommodated 1¼ pounds of green herb and that it was possible to string the wires 1 foot apart, having each tier of wires 2 feet from the next tier

below, which arrangement allowed for plenty of air and also economized all the space. However, it is a better plan to use trays. These can be supported in any convenient manner and can be used for any drug. They are convenient to handle, are easily stacked away when not in use, and if properly constructed will last for years. The construction of trays is described later.

It is not advisable to construct a drying house for air-drying alone, but rather to make one in which artificial heat can be supplied whenever necessary. The drying house shown in figure 6 can be used in this manner. The drying house illustrated in figure 3 was constructed for air-drying only. The numerous openings in this building allow for plenty of air circulation, but they also admit so much light that the drug loses its color by the time it is dry. A much better appearing drug could be obtained by making the openings narrow and fitting them with doors so that light could be shut out but air admitted. The slat ventilators in the peak of the building are of prime importance, for they furnish a means of allowing air circulation even when the windows are closed.

Fig. 3.—A drying house constructed for air-drying only.

DRYING WITH ARTIFICIAL HEAT.

There are numerous drying devices on the market which are available to the producer of crude drugs. Nearly all these, however, are intended primarily for drying fruits or vegetables or are designed to fit into large-scale factory operations. Any one of the fruit or vegetable driers could probably be utilized for drying crude drugs. If one of these driers is available and can be made to operate satisfactorily, the producer's drying problem is greatly simplified. The usual type of cook-stove drier has too small a capacity to be of any great use in drying large quantities of crude drugs. Such a drier could be used to advantage for small lots, especially of roots or seeds. Large driers, such as those described in Farmers' Bulletin 984, "Farm and Home Drying of Fruits and Vegetables," if they are available, can be used. The type of drier described in Bulletin 984 under the

heading "A prune tunnel evaporator" is very efficient and can readily be adapted to the drying of crude drugs. Likewise, tobacco-drying barns and other similar structures can be remodeled with little effort into efficient driers for drugs. If, however, a drying apparatus is to be constructed especially for the purpose of drying crude drugs, one of the following types is recommended.

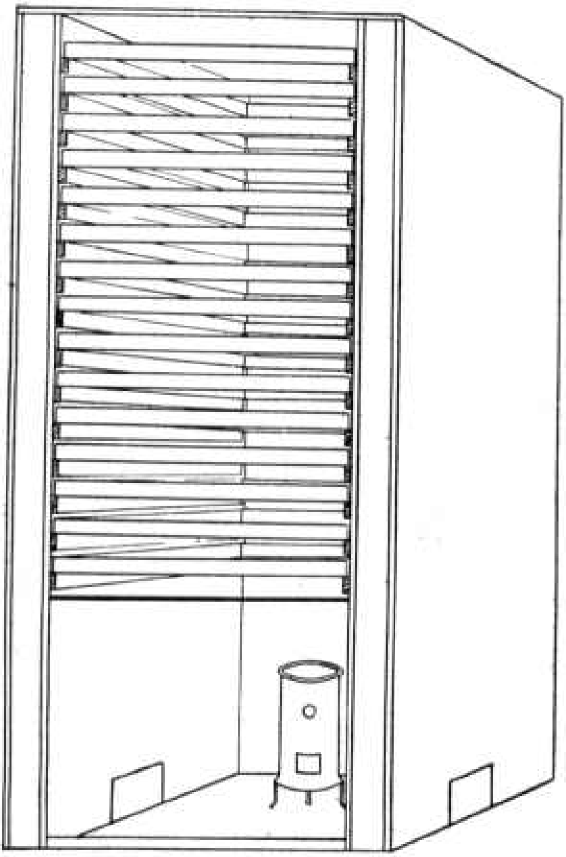

FIG. 4.—Plan of a small stove drier in perspective, with one side removed to show the arrangement of the stove and trays.

SMALL STOVE DRIER.

A drier of the stove type can be constructed at home at very little cost, and if the work is carefully done the drier will last for many years. A sketch of such a drier is given in figure 4. This drier is designed primarily to be heated by means of an oil stove. If a stove is used which burns wood or coal, the design is the same, but the dimensions are increased to meet the conditions. The drier is designed to accommodate 15 trays, each 3 by 3 feet; but more trays can easily be added if desired and if warranted by the available supply of heated air. A framework of 2 by 4 material is made in the form of an oblong box of such a size that the inside measurements will readily admit a tray 3 by 3 feet, allowing at least half an inch on every side of the tray for ease in inserting and removing from the drier. Tongue-and-groove lumber is nailed on the outside as well as on the inside of this 2 by 4 box frame; that is, it is sheeted up on both the outside and inside, thus forming an upright oblong box with open ends having a dead-air space in the walls. One side

of the upright box is closed with a tightly fitting door, which reaches from just below the bottom of the lowest tray to just above the top of the uppermost tray. This door can be constructed to swing on hinges or it can be removed entirely whenever it is desired to insert or remove trays from the drier. The top of the box is closed by means of tongue-and-groove lumber, and in it are arranged small hinged doors which are operated as ventilators. This top does not contain a dead-air space. At the bottom of the drier, on two opposite sides, sliding doors are so arranged as to control the inlet of air. The inside of the drier is covered with tin up to the support of the bottom of the first tray. Three inches under the first tray is a piece of sheet iron or tin, arranged so that it comes over the top of the stove and prevents the hot air of the stove from coming directly into contact with the material in the lower tray.

The trays are made of strips of lumber 2 inches wide and three-fourths of an inch thick nailed together so as to form a framework 3 by 3 feet, outside dimensions. To this framework wire netting of suitable mesh is fastened with staples and answers all purposes except for the drying of small seeds. Thin wooden strips are nailed around the framework over the netting, forming a protection which keeps the netting from tearing loose and also supplying a means by which the tray can easily be slid into and out of the drier. The trays are supported on cleats of wood 1 inch thick, 2 inches wide, and slightly less than 3 feet in length, firmly nailed to the sides of the drier. The drier is designed to be used within a room or shed where it is protected from the elements.

By proper manipulation of the air inlet and of the ventilators a drier constructed as outlined will give excellent service at little expense.

The total drying area of this type of drier is approximately 132 square feet, and it will accommodate 75 pounds of green leaf drug, such as belladonna or henbane. The capacity of the drier when filled with roots, such as burdock or dandelion, is approximately 150 pounds of green material. The length of the period of drying and the oil consumption will depend on the nature of the material to be dried, the temperature of the air, and the degree of heat from the stove. Experience will soon teach the attendant how to operate the stove and the vents in the drier so as to obtain the proper rate of drying at the minimum expense of time and fuel.

LARGE-TYPE DRIER.

For operators drying as much as several hundred pounds of green crude drugs a day a large commercial-sized drier must be provided. A very satisfactory type of drier, that will dry in approximately 24 hours 750 pounds of leaf drug, such as belladonna or henbane,

or 1,500 pounds of root drug, such as burdock or dandelion, is illustrated in figure 5. This drier is in operation at the present time, and is giving very satisfactory results, both as to the appearance of the finished product and the cost of the operation.

A drying house that will accommodate approximately 1,000 pounds of green leaf drugs or a correspondingly larger weight of green roots is illustrated in perspective in figure 6. This drying house is 14 feet 6 inches in length, 11 feet wide, and 10 feet 2 inches in height to the eaves. The end walls of the house are constructed of the usual 2 by 4 studs, sealed on the outside with ¾-inch ship-lap and on the inside with ¾-inch tongue-and-groove lumber. Building paper is nailed to the 2 by 4 inch studs, both on the outside and the inside, before putting on the boarding. The interior of the drier is cut into six compartments by partitions that extend from the floor to the line of the eaves. The partition that extends lengthwise through the center of the building is constructed of 2 by 4 inch studs, to which is nailed ¾-inch tongue-and-groove lumber, making the total width of the partition 5½ inches. The partitions that extend crosswise of the building are constructed of 2 by 4 inch studs so spaced in a staggered row as to make an 8-inch partition over all after the ¾-inch tongue-and-groove lumber has been nailed on. These 8-inch partitions are made thus wide to allow the easy opening of the heavy door of any one compartment without interfering with the adjoining compartment. If the partitions are narrower, the door of the compartment can not be made to swing open a sufficient distance to allow the removal of the trays without first opening the door of the adjoining compartment on the side nearest the door's hinges. Each of the six compartments is 4 feet 1 inch by 5 feet 1 inch, inside measurements. The top of each compartment is floored over with ¾-inch ship-lap or tongue-and-groove lumber on the upper side of the 2 by 6 inch stringers which form part of the framework of the building. Hinged doors 3 by 3 feet are set into this flooring over each compartment and so arranged as to be easy of manipulation by means of pulleys, with a rope which is run to the out-

FIG. 5.—Drying house constructed for both air-drying and artificial heat.

side of the building. The flow of air through the material can be partially controlled by regulating these doors. The floor of the entire building is composed of wire screen of quarter-inch mesh nailed to 2 by 6 inch stringers, conveniently spaced so as to support the partitions and also form part of the framework of the building.

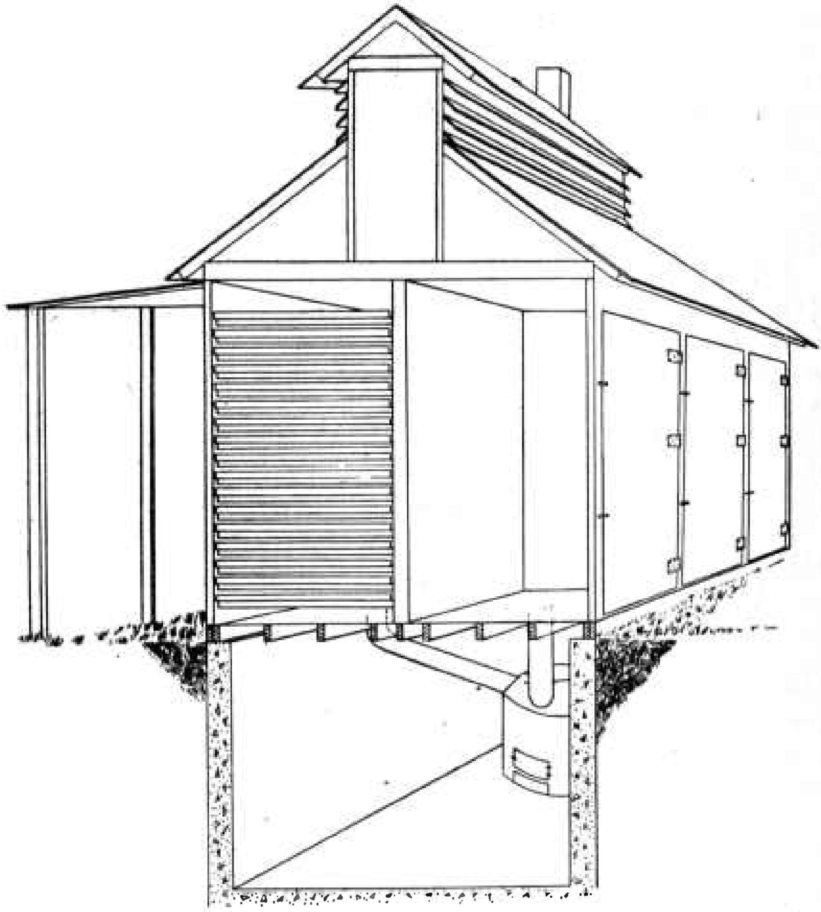

FIG. 6.—Plan of a commercial-size drier in perspective. The arrangement of the trays is shown in one compartment. The side roof on the right is not shown.

The compartments are large enough to accommodate trays 4 by 5 feet in size, outside dimensions, and each compartment holds 17 trays placed one above another, 6 inches being allowed from center to center of the tray supports. This is as great a number as can conveniently be loaded and placed in the drier and is also the maximum number which will permit proper drying without slowing down the drying on the upper trays. The trays are supported in the drier on

strips 2 by 2 inches by 5 feet, securely nailed to the side walls of the compartments.

The door of each compartment is made to fit snug against the frame, having a bevel edge which meets a similar bevel on the door frame. Strips of felt nailed on this bevel help to make a tight union between the door and the frame. The door is constructed of two thicknesses of tongue-and-groove lumber nailed together diagonally to give strength and with a double layer of building paper between the two. A door thus constructed will be approximately $1\frac{3}{4}$ inches thick and will be strong, owing to the diagonal construction. Each door is supported on three 5-inch strap hinges securely screwed or bolted on. Two or more bolt locks or locks similar to those used on cold-storage ice-room doors keep the door tightly closed while the drier is in operation.

A fixed ventilator is constructed in the roof, as shown in figure 6. This ventilator allows the ready exit of the warm moisture-laden air after it has passed through the stack of filled trays and the control door in the ceiling over each compartment. Wire of any convenient mesh is nailed on the inside of the fixed ventilator, to prevent the entrance of birds or small animals. The roofs of the building and of the ventilator are covered with a good grade of roofing paper, metal roofing, or shingles, as may be convenient or desired.

The drying house is so designed that a roof is built on either side of the building, extending out from the building at least 6 feet. This roof has a very slight slope, so that at the outer or eaves side it will not interfere with the removal of the top tray. These roofs serve to keep rain and sun off the contents of the trays as they are being filled or emptied. It will be noted (fig. 5) that the roof of the building proper extends over a sufficient distance to make a cover, under which the trays are filled and emptied. This arrangement, while satisfactory, is wasteful of material and space, for not all the space from the top of the trays to a point directly above the doors on the roof is utilized. In the particular drying house illustrated in figure 5 the space not occupied, because of the design of the building, amounts approximately to 35 per cent of the cubic capacity of the entire building. This waste space is saved in the design illustrated in figure 6.

The heating arrangement for the drying house consists of a hot-air furnace. This is placed beneath the center of the building in a cellar or basement, and hot-air pipes run from the furnace to the center of each compartment. Pipes 8 inches in diameter supply heat to the middle compartments, while the end compartments are supplied by 12-inch pipes. Over the outlet of each hot-air pipe a piece of sheet iron 2 by 2 feet is placed about 6 inches from the floor level.

This deflects the stream of heated air and causes it to spread throughout the compartment. It also keeps the hot air from coming into direct contact with the material in the first tray. Each hot-air distributing pipe is fitted with a damper, by means of which the operator can regulate the flow of heated air supplied to each compartment and close off the heat from any compartment when desired. The smoke flue extends from the furnace to one end of the building, where it makes a half turn and enters the chimney on the opposite end. By extending the flue, as indicated, considerable heat is obtained by radiation which otherwise would be lost. The nature of the floor under the compartments permits the easy utilization of the heat from the flue as well as the heat which radiates from the body of the furnace. A suitable cold-air intake runs from the furnace to the outside of the basement. The chimney is constructed of brick, hollow tile, clay drain pipe, or any suitable material.

The basement is of the same size as the building, outside dimensions. The walls are thick enough to make a substantial structure, and may be built of any suitable material, although concrete is to be preferred. There is enough space for the furnace and for the storage of a small quantity of coal.

The drying house illustrated in figure 5 is on a hillside. This allows for the construction of a basement with low cost for excavation and also permits ready access from the ground level to the drying trays. If no such natural advantage can be utilized, the drying house can be placed over an excavation sufficiently deep to bring the floor of the building approximately 8 inches above the ground level, and a stairway can be built in an excavation that leads to a door set in the wall of the basement. A covering similar to the outside cellar door of a dwelling house prevents rain, snow, or refuse from entering the stairway and also tends to prevent the loss of heat by radiation.

DRYING TRAYS.

Trays suitable for use in a drying house like the one just described are easily constructed. They are 4 by 5 feet, outside measurements, and consist of a framework of $\frac{3}{4}$-inch wooden strips $2\frac{3}{4}$ inches wide, with an additional similar wooden strip nailed crosswise midway of the longest side of the tray. The bottom is a screen of any small mesh. For most drugs $\frac{1}{4}$-inch mesh is desirable, but where seeds are to be dried a smaller mesh is necessary; a mesh greater than quarter inch is not recommended. After the screen bottom has been stapled to the framework a strip of wood three-quarters by three-quarters of an inch is nailed over the edge of the screen and into each side and end of the frame. This strip not only protects the edge of the screen but also acts as a shoe for the tray, making it slip readily on the supports

nailed to the side of the drying compartment. To strengthen the tray, small strips of iron may be nailed across each corner. The lumber used for trays should be light and well seasoned.

A tray constructed as outlined contains approximately 18.6 square feet of drying area. With 17 trays in each compartment and 6 compartments in the drying house, there are about 1,900 square feet of drying area in a building like that in figure 6. Each square foot of drying surface accommodates about half a pound of fresh leaf drug or 1 pound of fresh root drug.

MANAGEMENT.

The regulation of a drier is chiefly a matter of control of the heat and the flow of air. In using the hot-air furnace both heat and flow of air are controlled as one, since the flow of air is increased or decreased with the raising or lowering of the temperature. The rate of heating necessary to dry any particular drug is learned only through experience. A broad general rule, however, is to use extremely low heat on drugs in which the value depends upon a volatile constituent, a very moderate heat on ordinary leaf and herb drugs, and a moderate heat on root and bark drugs. Never employ the highest temperature at the beginning of drying, but start with a low temperature and gradually increase up to the desired degree. At no time is it desirable to employ a high temperature.

CARE OF DRIED CRUDE DRUGS.

After the crude drugs are dried they should be marketed as soon as convenient. It rarely pays to hold drugs in storage for any extended length of time.

A very convenient method for packing the dry drug materials is to bale them in an ordinary paper-baling machine. The bales should be wrapped in burlap and stored in a moderately cool, dark place. When the drug is first removed from the drying house it should be allowed to remain for several days before baling on a clean floor or in any clean bin protected from the light. During this period it will take up moisture from the atmosphere and become less brittle and easier to handle. Crude drugs can be packed in burlap sacks, in boxes, or in barrels. Paper cartons are often used to hold the baled drug. The bale neatly wrapped in burlap is the cheapest and most practicable form of preparation for shipment.

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